

# EPICS IOC OF WINDOWSXP-BASED OSCILLOSCOPE FOR FAST BPM DATA ACQUISITION SYSTEM

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## Abstract

The KEK Linac is a 600-m-long injector that delivers electron/positron beam to the four independent rings. The non-destructive beam position monitor (BPM) is an indispensable diagnostic tool for a long-term stable beam operation. In the KEK Linac, around one hundred BPMs with the four strip-line type electrodes are used for the beam orbit measurement. The beam orbit data is used for the beam orbit and energy feedback loops. The previous BPM data acquisition (DAQ) system consists of a VME CPU and a digital oscilloscope, and it has been installed more than decade ago. Although the maximum linac beam repetition rate is 50 Hz, the maximum DAQ rate of previous system is about 1 Hz limited by an oscilloscope performance.

Recently, we have started a fast beam-mode switch operation aiming the simultaneous injection between KEKB and PF rings, in which the fast beam position measurement of 50 Hz is strongly required. For this purpose, we developed a new BPM DAQ system using a WindowsXP-based fast digital oscilloscope. In this paper, we will present the system description of the new DAQ system and the results of performance test in detail.

## INTRODUCTION

The KEK Linac sequentially generates the beams in different modes and delivers them to the following four storage rings: a KEKB low-energy ring (LER; 3.5 GeV/positron), a KEKB high-energy ring (HER; 8 GeV/electron), a Photon Factory ring (PF ring; 2.5 GeV/electron) and an Advanced Ring for pulse x-rays (PF-AR; 3 GeV/electron). So far, a beam injection to the PF ring and PF-AR has been carried out twice a day, whereas the KEKB rings are operated by a continuous injection mode (CIM) so that the stored current is kept constant. During the CIM operation, the linac beam modes are frequently switched so that the all settings of magnets, rf phases and timings are changed according to the HER and LER beam injection. In the typical CIM operation, the linac parameters are frequently changed in every 30 s.

For increasing the stored current stability, the faster

linac beam-mode switch between LER and HER is strongly desired. In addition, the PF top-up injection is also strongly required even during the KEKB CIM operation. For these reasons, the injector upgrade project has been started since 2004 so that the PF top-up never interrupts the CIM of KEKB [1, 2, 3]. This upgrade was achieved in April 2009. Recently, the linac beam can be delivered to the different rings in every 20 ms interval.

For the simultaneous top-up injection between PF and the KEKB rings, a higher-performance new BPM DAQ system is strongly required since the beam position measurement should be carried out in pulse-by-pulse of 50 Hz. For this purpose, we developed the new BPM DAQ system and replaced all previous system by the new one.

## BPM DAQ SYSTEM,

### System Overview

For a higher availability of beam operation, many kinds of feedback loops have been developed and utilized to stabilize the beam orbit, energy and energy spread [4, 5, 6]. These feedback loops make use of the beam position information acquired by the non-destructive BPMs [7]. About one hundred stripline-type BPMs have been installed in the KEK Linac.

The twenty front-end systems have been installed in the linac klystron gallery at a nearly equal interval along the beam line. The each DAQ system deals with the analogue signals of 3 to 12 BPMs. A schematic drawing the former DAQ system are shown in Fig. 1. It consists of a VME computer (OS-9 operating system with a 68060 microprocessor of 50 MHz), a digital oscilloscope (Tektronics TDS680B/C; 5 GSa/s, 2 channels, 8 bits) as a waveform digitizer, and two signal combiners in a cable combiner box.

The four signals coming from one BPM are fed to two signal combiners (vertical and horizontal) together with the signals from other BPMs. The delay cables corresponding to a 7 ns time delay are used to avoid waveform overlaps at the signal combiners. The two combined signals are digitized by an oscilloscope at a sampling rate of 5 GSa/s. The digitized signals are

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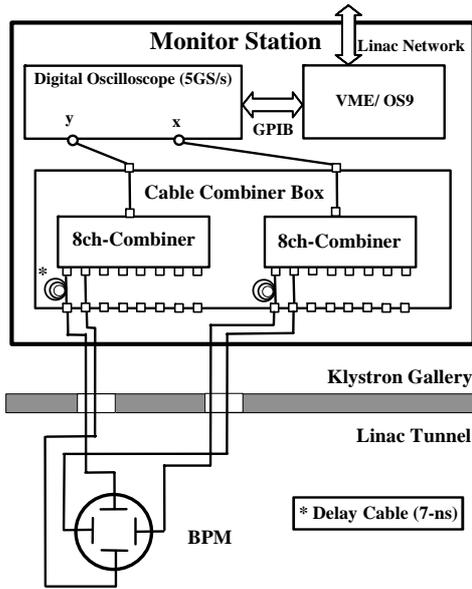


Figure 1: Schematic drawing of the previous BPM DAQ system.

analyzed by a VME CPU in order to deduce the beam parameters (beam charge, horizontal position, vertical position), taking into account the calibration coefficients.

The trigger pulse signals, which are synchronized with the linac beam, are provided to all DAQ systems at 0.7 Hz. These signals are used to start the data taking cycle of the each DAQ system. The trigger rate is limited by the GPIB communication throughput between the VME computer and the oscilloscope.

### New System

We adopted a WindowsXP-based fast digital oscilloscope (Tektronix DPO7104; 10 GSa/s, 4 channels, 8 bits, CPU P4/3.4 GHz, Gigabit-Ethernet) as a new BPM DAQ system. Its photograph is shown in Fig. 2. In the new DAQ system, a VME computer and an old oscilloscope was replaced by a fast digital oscilloscope as shown in Fig. 3. In the new system, CH1/CH2 and CH3/CH4 are used for the low charge modes and the high charge mode, respectively since it is impossible to change the vertical scale of oscilloscope in every 50 Hz

Because the Experimental Physics and Industrial Control System (EPICS) has been utilized for the KEK

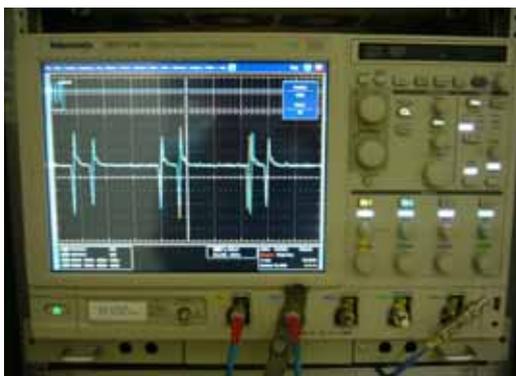


Figure 2: Photograph of the new BPM DAQ System.

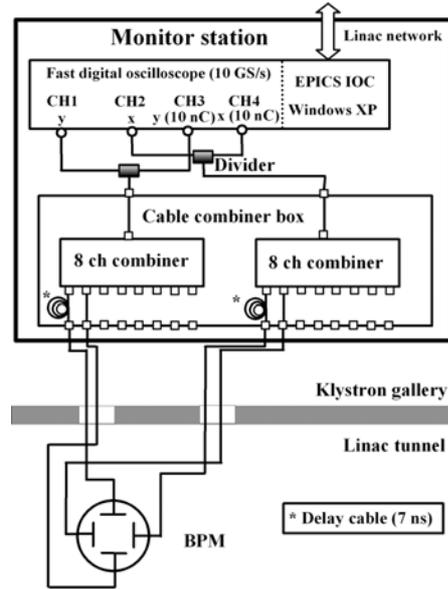


Figure 3: Schematic drawing of the new BPM DAQ system.

Linac control system, we developed the EPICS Input/Output Controller (IOC) for the new DAQ system by using Microsoft Visual Studio 2005 C++ (MSVSC++), TekVISA and EPICS R3.14.8.2 libraries. The new DAQ software is running on the fast oscilloscope, and the each oscilloscope can work as EPICS IOC.

## PERFORMANCE TEST

### Evaluation of DAQ Performance

We evaluated the speed performance of waveform signal acquisition. The test software was also developed by MSVSC++, TekVISA and EPICS R3.14.8.2 environment. In this test, we changed the number of used oscilloscope channels from one to four and the waveform length from 1 k to 500 k data points independently. The test software was carried out on the oscilloscope. During all performance tests, the display update functionality of the oscilloscope was disabled for enhancing the performance of DAQ speed, and the rectangle shaped waveform of 15 MHz was used for an external trigger

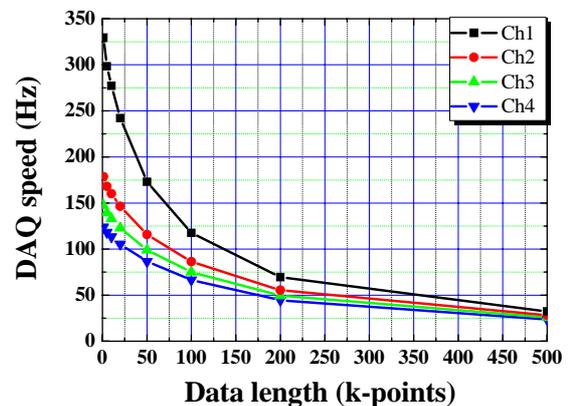


Figure 4: DAQ performance of the fast digital oscilloscope.

signal.

Figure 4 shows the results of performance tests. The dotted lines mean the DAQ speed averaged over 100 times measurements for the corresponding number of used channels. The simultaneous acquisition of two channel signals about 20 k data point length is needed for the practical beam operation. From Fig. 4, it corresponds to the DAQ speed of around 150 Hz. Even taking into account the computation time, we confirmed that the new DAQ system has enough high performance for the 50 Hz beam position measurement.

### Beam Test and Beam Orbit Display Panel

The beam test using the new DAQ system was carried out for confirming the long term system stability. For this beam test, we used the BPM data of SP\_R0\_42 installed in the arc section and the beam mode pattern corresponding to the KEK electron (1 nC), KEKB positron (10 nC) and PF electron (0.1 nC) mode combination, in which the beam mode is switched in every 20 ms interval. The test result of two hours beam charge measurement is shown in Fig. 5. In this figure, the red, blue and black dots mean the measured beam charge of KEKB electron, positron and PF modes. From this result, it was confirmed that the new system can work properly up to 50 Hz beam measurement.

Figure 6 shows the example of beam orbit display panel developed by using Python script language. During the daily beam operation, the three different panels are

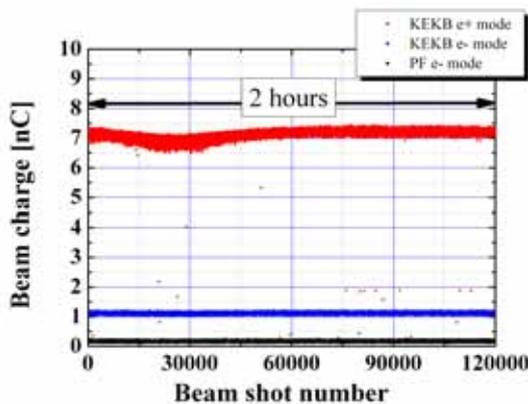


Figure 5: Test results of two hours beam charge measurement.

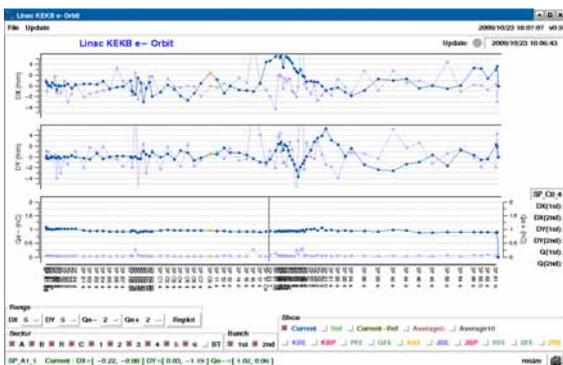


Figure 6: Example of the beam orbit display panel.

launched, and each of them shows the beam position and charge information corresponding to the specific beam mode.

## SUMMARY AND FUTURE PLAN

The KEK injector linac upgrade was carried out for the simultaneous operation between the KEKB CIM and the PF top-up. For this purpose, a BPM DAQ system upgrade is strongly required for the fast beam position measurement up to 50 Hz since the previous DAQ system has about 1 Hz data acquisition performance. We developed the new BPM DAQ system by using a WindowsXP-based fast digital oscilloscope, and each of them can work as EPICS IOC.

All old DAQ systems have been already replaced by new one. The new system is stably utilized for the daily operation up to 50 Hz measurement. A similar system was also developed and utilized for the BPM DAQ system of KEKB beam transport [8]. In the near future, we will study the correlation between the fast fluctuation of beam position and other parameters like rf phase/amplitude, and its results will be presented elsewhere.

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